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ABSTRACT

Some specific aspects of the process of discovery are explored as they are experienced in the visual arts and the physical sciences. Both fields use the same visual/brain processing system, and both disciplines share an imaginative and productive interest in the disciplined use of imagistic thinking. Many productive interactions between visual artists and scientists have been noted, including such fields as scientific illustration and the representation of research results or the illustration of science fiction. A factual basis for exploring the methods of visual discovery can be found in the literature on brain hemisphere function. Personal experiences of the author and examinations of one of Michelangelo's Sistine Chapel frescos and a Picasso painting illustrate a close connection between the domains of art and science. A scientific/artistic way of knowing, as distinct from analytical proof, logical understanding, or purely subjective reactions, is proposed. This synchronistic way of knowing concentrates on the visual and imagistic formation of ideas, informed by critical thinking, and leads to a type of purely visual logic. Seven figures and one table illustrate the discussion. (Contains 23 references.) (SLD)

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Visual Links: Discovery in Art and Science

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by
Dennis M. Dake

This paper will explore some specific aspects of the relationship between the process of discovery as experienced in art and science. The use of the visual perception system is viewed, in this exploration, as central to discovering the links that exist between the visual arts and the physical sciences. A primary assumption here is that both classes of human endeavor must utilize and depend upon the same visual/brain processing system. Both disciplines, therefore, share a particular imaginative and productive interest in the disciplined use of imagistic thinking. Jacob Bronowski has pointed out the importance of this connection for our educational system. "Science uses images and experiments with imaginary situations, exactly as art does....To believe otherwise, to suppose that science does not need imagination, is one of the sad fallacies of our laggard education." (Bronowski, 1978, p 20)

That disciplined and visually based thought has been utilized to help the scientist discover new knowledge, can be readily seen in the notebooks of inventors such as Alexandar Graham Bell, or of scientists of renown such as Charles Darwin, who frequently sketched an abstract branching structure as he formulated his ideas on biological evolution.

When looking at the evolution of visual ideas in the sketchbooks of artists such as British sculptor Henry Moore, one sees the same interest in evolving the structural equivalent for an idea or an experience developing in the mind. Individuals functioning within both art and science disciplines are reaching out to grasp things not currently existing in the world of perception. Many books, scholarly articles, and monographs have been written on this relationship between art and science, but most that were reviewed in the preparation of this paper were found to be heavily dominated by written explanation and quantifiable evidence. They offered only meager visual documentation of the remarkable similiarities between the visual processes and products of creative discovery in the fields of art and science.

Some Interesting Connections

There are many productive interactions between visual artists and scientists, which though they are becoming increasingly prevalent on the contemporary scene are not the particular focus of this discussion.

1. Artists interested in and using science and technology.

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For years, contemporary artists have collaborated with scientists and technologists. Of particular note was the EAT group, founded in the 1960's. Today many artists use the tools and knowledge provided by modern science, such as neon lights and computer graphics technologies. Artists have also been interested in looking at the visual phenomena of the scientific world. A particular case in point are the group of murals on the theme of science and industry painted in 1933 in Detroit by the Mexican muralist, Diego Rivera.

2. Influences and interactions of scientists and artists on one another.

From the discovery of mathematical principles underlying linear perspective in the Renaissance to the remarkable common exploration of spectrum analysis and optics conducted in the 19th century by the French Impressionist painters and optical scientists, such as Chevreul, there is a long history of close relationships of influence and common interest between individuals calling themselves artists and scientists. Many have noted the influences of Freudian psychology upon the surrealists in the early 20th century and the effect of the photographic analysis of motion on futurist paintings, such as Marcel DuChamp's Nude Descending a Staircase.

3. Scientific illustration.

Illustrators have been cooperatively working with scientific colleagues for hundreds of years to record and accurately communicate information that can best be understood in a visual form. A great deal of information can be clearly conveyed in an illustration where even a photograph might be confusing. Many phenomena which scientists study are highly abstract and can be best communicated to a lay audience with accompanying visual representations or simulations.

4. Scientific visualization.

Scientific visualization is becoming an increasingly complex and important field in the advancement of science. Individuals with both artistic and scientific training are employed in this field. They frequently use state of the art computer technology to visualize large sets of data and understand the complex interactions. Other scientists work with simpler manual technologies to visualize and explore imaginative relationships within the physical world through physical model making using common materials. Often discoveries are made in this way.

5. Exploration of the properties of materials.

In retrospect, the elaborate techniques which artists have created over the centuries to push materials into forms for expressive and utilitarian purposes, can in the hands of an analytically minded scientist, yield new discoveries on the nature of materials and forces in the physical world. An exhibit of historical objects from the earliest human civilizations, entitled "Aspects of Science", was held at Massachusetts Institute of Technology in 1978. In this exhibit many discoveries which have been directly useful to the development of scientific fields, particularly Materials Science, were displayed.

6. Exploration of information hidden from view.

Scientists in many fields require the use of photomicrography with electron and other devices to reveal important and meaningful structural relationships hidden

in the world of the very small. Astronomers use optical and radio wave telescopes to clarify visual phenomena in the world of the unimaginably large. Medical researchers and doctors have CAT scans with three dimensional modeling and Magnetic Resonance Imaging to help them discover truths hidden within the human body, without the need for exploratory surgery.

7. Representation of scientific research results.

Artists are often called upon to design charts, graphs and illustrations representing and communicating the results of scientific research. Clear visual representation of important data and conclusions can carry the messages of science to a distant future.

8. Science fiction art.

Undoubtedly some of the most imaginative of interactions between science and art occur in the realm of science fiction. Movies and television shows, such as the Star Trek or Star Wars series, visualize for a mass audience evidence of the potential for scientific ideas projected forward in time.

9. Visual discoveries outside the boundaries of conscious reasoning.

Perhaps the closest type of science/art interaction relates to the use of automous imagery, such as dreams, in the process of discovery. The best known example from science is the oft cited example of the chemist Kekule reporting that he fell asleep and dreamed of a snake swallowing its tail. Upon waking, this visual configuration gave him the revolutionary structural idea for understanding the structure of certain organic compounds such as the benzene ring. The use of autonomous imagery is, of course, well established in the work of artists, with the dreamlike imagery of the surrealists being the most obvious case.

Remarkable Similiarities

In 1963, *Look Magazine* published a visually interesting article authored by Charlotte Willard, entitled, "How Science and Art are Changing our View of Reality." This article contained several visual comparisons demonstrating the remarkable visual similiarities between what were then some of the most recent "discoveries" in the fields of art and science. For example, an abstract painting by the surrealist, Roberto Matta entitled, "Listen to Living" was compared closely in form with the scientific visualizations of Photothermoelastics researcher, Dr. Herbert Decker. In these visual explorations, both artist and scientist clearly sought to understand the world through similiar flowing organic forms and colors. While the verbal explanations of artists and scientists about their intentions, methods, and purposes undoubtedly vary widely, the visual comparison is striking and not to be denied. Both disciplines look at and manipulate the same visual elements from the same visual world.

A Scientific Basis for Visual Discovery

A factual basis for exploring the methods of creative visual discovery can be found in the literature on lateralized functions of the hemispheres of the brain. Specifically, a 1976 study by Levy and Trevarthen (Springer & Deutsch, 1981) (figure 1) demonstrated that the left hemisphere of split-brain patients tended to select matches for presented visual stimuli (pictures of a cake, scissors and

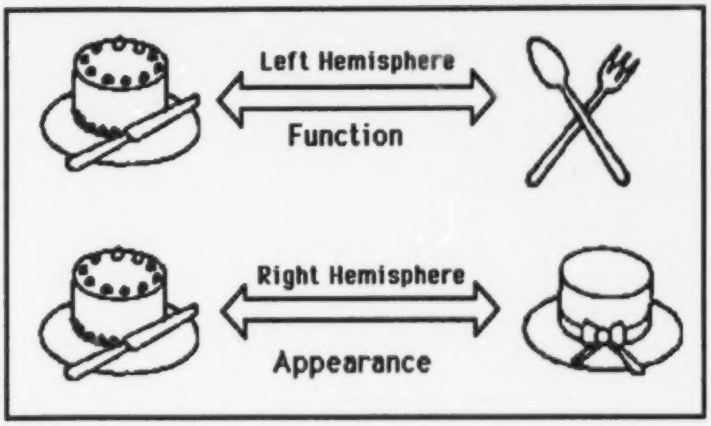

Figure 1: Laterality study for hemispheric functions

glasses, etc.) from a group of other stimuli (hat, spoon and fork, and an arrangement of needle and thread) based on function. For example when shown a cake on a plate the subject selected the spoon and fork as implements with which to eat the cake. Most current intelligence measuring instruments use such visual reasoning concerning function. The study, published in *Journal of Experimental Psychology*, concluded that, while the left hemisphere tends to match by function, the subjects' right hemispheres tended to match by appearance. When the right hemisphere was shown the visual stimuli of the cake, it picked as the "best" match a visually and structurally similiar visual respresentation of a hat with a wide brim. It would appear that this capacity for "thinking by appearance" could be part of the basis for the reported mental ability of creative individuals to make great discoveries by means of imagery alone.

The most famous report by a creative individual of the ability to generate new thoughts by heavily visual means is the Albert Einstein answer to a questionnaire about his working methods. "The words of the language, as they are written and spoken, do not seem to play any role in my mechanisms of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be voluntarily reproduced and combined ...The above mentioned elements are in my case of visual and some of muscular type". (Ghiselin, 1952, p 43)

Thinking by appearance leads to the abilty to be able to stretch and break traditional conceptual "boundries" around ideas. This boundary-stretching and boundary-breaking confers on the individual the ability to create analogies and metaphors for experience. From this unique new point of view, new discoveries are possible. Arthur Koestler has proposed for this creative thinking ability the term "bisociative thinking". He proposed that this ability is the basis of all creativity whether in science or art. A particularly striking example of bisociation in the visual arts is "Bulls Head" by Pablo Picasso, a 1943 sculptural assemblage of the handlebars and seat of a bicycle, which, when arranged vertically, instantly acquired the gestalt structure of the head of a bull.

Examples of Visual Discovery

Scientists have looked for the perceptually based evidence of discovery by artists for further study by the scientific method. Leonardo da Vinci's journals and notebooks are a particularly rich

source of precise visual information. Both scientists and artists can see in this Renaissance artist's visual forms, accurate records of phenomena and relationships of the physical world. One fluid mechanics scientist at the University of Iowa even believes that Leonardo was the first scientist in that field. He uses the drawings of the flows of eddies and tides in the notebooks of daVinci as a research base for advancing fluid mechanics.

The *Look* magazine article mentioned earlier made a visual comparison between a photomicrograph of the DNA modecule created by Dr. Roman Vishniac with the organic form explorations of artist Arshile Gorky. Interest in the structure of the basic unit of life has been present in both scientists and artists. In 1968 Science Digest identified a shaped canvas by Abraham Joel Tobias entitled, "Genesis - Male and Female" as an intuitive visual understanding of the the double helix structure of DNA some 18 years before Drs. Watson and Crick and their team made a spiral model from scientific laboratory equipment to establish the relationships between various available data. This discovery earned Watson and Crick the Nobel Prize. The artist remains largely unknown today.

Look magazine also drew attention to the structure of nonobjective paintings created by American artist Jackson Pollock in the early 1950's. These were compared to the later discovery, revealed in a photomicrograph, of the structure of electrical waves traveling through the cortex of the human brain by D.A. Scholl of the University of London. That Jackson Pollock, using a novel and often ridiculed method of applying paint to canvas, should be compared to the careful and meticulous disciplined work of scientists may seem almost ludicrous in the current cultural climate. However, if we consider that Pollock said his intention was "to paint himself into his paintings," this connection may be seen as potentially more productive. Pollock's methods also grew out of two other sources which establish the connection between his visual explorations and the structure of brain activity. First, he began his nonobjective explorations at the suggestion of his psychoanalyst who felt that, since he was a visual artist, he might better access his stream of consciousness in visual rather than verbal symbols. Secondly, Pollock drew inspiration for his method of applying paint to a canvas laid flat on the floor from his interest in the Navaho sand paintings on the ground. That these sand paintings are created to effect a spiritual and medical cure for an ill member of the tribe creates a rich analogy for the ability to control mental activity, which the personally troubled Pollock would have found compelling.

Two Personal Experiences with Visual Discovery

This connection between visual form and thought is further amplified by two personal experiences of this author. In 1985, after completing a series of paintings (such as the one shown in Figure 2) based on the twisted forms of cloth about to be tie dyed, I learned from a chemist that the forms which I had been exploring were essentially Fractal mathematical structures. When I was shown the computer visualization of a Fractal, (see Figure 3) I had to agree that there was a remarkable similarity between my slowly developed intuitive forms and the symbolizations created by mathemati-

Figure 2: Thought Structure, Dennis M. Dake Watercolor, 24 x 30 ", 1982

cians for their discoveries in assymetrical mathematical equations. That I had from the beginning called the paintings in my series " thought structures" made the metaphor that much richer for me.

A second example which depended upon an appreciation for visual comparison, intuitively arrived at, occurred some 12 years ago as I sat looking at a reproduction of Michaelangelo's "Creation of Adam" from the Sistine Chapel, (Figure 4). The form which has usually been

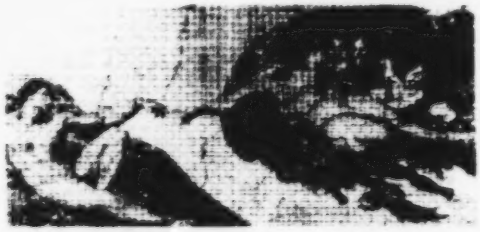

Figure 4: Creation of Adam, Michelangelo, Sistine Ceiling, Vatican, Rome

described by art historians as "God emerging out of a void" to awaken a sleeping Adam seemed to me, in a way I could not describe in words, to be strangely familiar; not the logical connection to a void, but to something else. As I

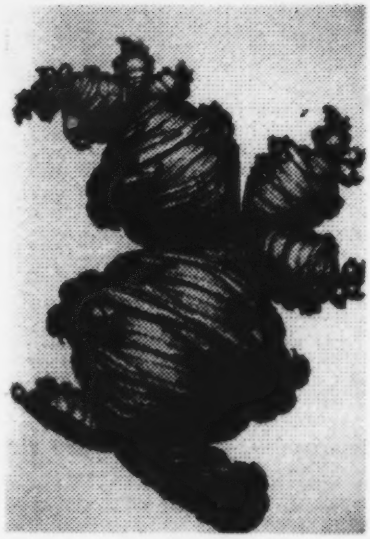

Figure 3: Fractal (Smithsonian Magazine)

Quaternionic Julia Set by Alan Lorton from *The Fractal Geometry of Nature* by Bernoit Mandelbrot, W.H. Freeman and Co., 1982 - Reproduced by permission.

Figure 5: Cross section- Human Brain

Medial Surface of Sagittal Section from *Atlas of Human Brain* by M. Roberts and J Hanaway, Lea and Febiger, 1970, Reproduced by permission.

stared at the painting, the intuitive thought arrived, seemingly unbidden, that this was the structure of the human brain which I had been studying in the previous months in preparation for a lecture on mental process in art. When I located the photograph of a bisected human brain (see Figure 5) the structural similiarity was astonishing; enough so, that I made

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the visual aid (figure 6) to illustrate the most important structural similarities.

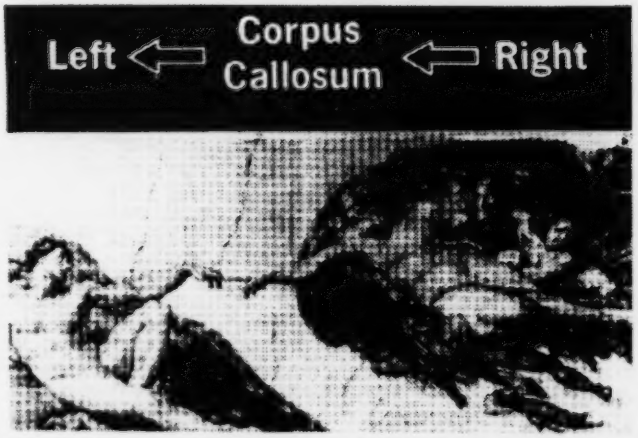
My intuitive conclusion was never published because I felt I lacked the scientific expertise to draw this inference. However, in 1990, a medical doctor came to the same conclusion as I had and published his structural comparison in the *Journal of the American Medical Association* under the title, "An Interpretation of Michelangelo's Creation of Adam based on Neuroanatomy." Dr. Frank Meshberger's careful analysis of structural similarities is quite believable if we

Figure 6: Michaelangelo's form outlined to show structural similiarities to form of human brain. (Original visual,1982)

factor in the knowledge that Michelangelo was known to have dissected human cadavers to gain knowledge of anatomy.

Within the art history community Dr. Meshberger's thesis has raised a great deal of controversy. Many critics contend that 16th century man could not possibly have had this knowledge about the importance of brain structure. Without conscious intent these critics suggest no visual discovery of knowledge can be attributed to Michelangelo. Given the many clear points of visual comparison made by Dr. Meshberger, it is strange indeed that his paper should have raised such opposition. Perhaps the opposition is so great because admitting to the possibility of knowledge gained by visual means, hundreds of years before it is codified by the scientific community, could lead to some unsettling extended analogies. In Figure 7 I have suggested that if the viewer reads sturucturally the Creation of Adam it suggests that Michelangelo not only knew of the structure of the brain, but also chose very insightfully the right hemisphere of the brain. Contemporary hemispheric laterality studies have suggested that the right hemisphere processes information metaphorically and synthetically. These processes then created the potential for rational, logical conscious thought in humans. The spark passing between the two outstretched fingers passes an electrical charge to an already physically developed left hemisphere (Adam), endowing him with rational reason and consciousness. To quote Bob Samples, author of

Figure 7: Creation of Adam as visual knowledge of Hemispheric Laterality.



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the book, *The Metaphoric Mind*, "The metaphoric mind includes rationality, linearity and logic - for it created them." (Samples, 1976, p 60)

The final example of visual discovery is perhaps the most interesting and controversial. In 1907 Pablo Picasso completed a painting which came to be called De Moiselles D'Avignon. It is regarded as the precursor of the revolutionary artistic language of cubism. Several authors have drawn attention to the relationship of cubism to the new physics, which emerged at the same time. (Einstein's Special Theory of Relativity was published in 1905). One of the best known comparisons was presented in a 1949 paper by Paul M. Laporte. Laporte pointed out that the cubist artists' interest in the visual intensity (energy) of their subject form (mass) have their equivalent in the energy/mass relationship of the new post-Newtonian physics. Further, he pointed out that cubism used a simultaneity of viewpoints within a single format to depict multiple movements in space, calling to mind both the time/space continuum and Einstein's assertion that kinethetics, along with visual imagery, were the basis of his thinking processes.

Laporte sent a copy of his paper, "Cubism and Physics", to Einstein for his reaction and reported his response to the thesis in a second paper. The movement of multiple viewpoints suggested by cubism seemed to Einstein to be at odds with the invariance of laws of nature which he had arrived at logically. His conclusion was that, "This new artistic language has nothing in common with the theory of relativity." (Laporte, 1966)

Picasso, in 1972, also took pains to deny connections between art and science. His statement even suggests that it is harmful to art to pursue connections to science. "Mathematics, trigonometry, chemistry, psychoanalysis, music and whatnot have been related to cubism to give it an easier interpretation. All this has been pure literature, not to say nonsense, which brought bad results, blinding people with theories. Cubism has kept itself within the limits and limitations of painting, never pretending to go beyond it." (Ashton, 1972, quoted in Mermoz, 1981) This mutual rebuff, coming so forcefully from both sides of the creative gulf between art and science raises an interesting question: Why do both the scientific and artistic disciplines insist so completely on the mutually exclusivity of their discoveries?

Dominance of Verbal Explication

A second related scientific experiment with split brain patients may lay a foundation for understanding why, with such compelling visual evidence to consider, the conclusions of both scientists and artists reject the possibility of synchronism of discovery. A 1978 experiment by Gazzaniga and LeDoux (Springer & Deutsch, 1981) found evidence of an interrupting and over-riding function of left hemispheric linear logic. When a split brain subject in this experiment was simultaneously shown differing stimuli to the left and right hemispheres of the brain (a drawing of a chicken's head to the left side of the brain and a winter's snow scene to the right side of the brain), matching selections from a group of presented visuals differed depending upon the hand used to point out the selection. The logical left hemisphere directed the right hand to select a drawing of a chicken's claw as the "best match"

for the stimuli it had been shown. However when asked by the researcher why the left hand had alternatively selected as "best match" a picture of a snow shovel, the subject answered, "to clean out the chicken shed." The obvious visual based logic of needing the shovel to clear the snow covered sidewalk was not consciously apparent to the subject.

Gazzaniga and LeDoux concluded that this over-riding system has evolved to help us "construct a reality based on actual behavior" and thereby see ourselves as single, purposeful beings. It appears then, that the verbal processing portions of the left hemisphere of the brain do not always know the origins of our actions or the meanings hiding behind appearances. The right hemisphere's ability to think by appearances serves as a complementary intelligent function of the mind to counterbalance the dominance of

Table 1: A View of Art and Science from the Left Hemisphere.

SCIENCE	ART
Precise	Diffuse, vaguely enriching
Rigorous	Playful only
Objective	Subjective
Explicit definition	Evocative spirit

one brain system. Without this complementary balance, the picture drawn in table 1 comes, in our culture, to be the chauvinistic, executive controlling view of the left hemisphere.

This one-sided view leads to a decidedly restricted line of inquiry into the creative functions of the human mind. This view holds that only that which can be explicitly stated as intentional can be accepted as a legitimate, intelligent function of mind. As evidenced from the dismissive quote from Picasso, most artists have not tended to think in terms of scientific theories or even always with conscious attention. Following the purely visual exploratory discipline of painting, drawing, or sculpture, artists intuitively pursue visual form knowledge for its own sake, foregoing verbal explication.

The problem with intentionality as the sole governing principle for visual meaning was clearly stated by Rudolf Arnheim in his analysis of Picasso's painting Guernica. "....it will be evident that deliberate, conscious reasoning and decision constitute only small fragments of the total process, and that therefore any psychological investigation is bound to describe happenings of which the person himself was not aware. The assertion that the 'artist never thought of this' has no bearing on the validity of the interpretation, since the artist, like any other person, does not know what he thought below the level of awareness." (Arnheim, 1962, p 17)

Given the current state of understanding of this lack of cooperation between these two functions of the brain, and given the imperialism of the linear, verbal left hemisphere, it appears that the potential for visual metaphoric discovery is often downgraded and the forceful separation of art and science disciplines is maintained. In his 1976 book, *The Metaphoric Mind* author Bob Samples drew attention to this problem for modern life.

"Albert Einstein called the intuitive or metaphoric mind a sacred gift. He added that the rational mind was a faithful servant. It is paradoxical that in the context of modern life we have begun to worship the servant and defile the devine." (Samples, 1976, p 26) This sadly seems to be the state of understanding within western culture, where the historic understanding of synchronistic visual discovery is not valued or promoted. Perhaps the uncertainty principle of physics (phenomena are altered and accuracy of measurements made more uncertain by the very presence of the observer) applies to the verbal, analytical processes when attempting to explore and understand the processes of visual discovery.

Synchronism: A Visual Way of Knowing

This paper proposes a scientific/ artistic way of knowing as distinct from analytical proof, logical understanding or purely subjective reactions. Jacob Bronowski again lays out the agenda in stark terms, "The human mind works with images, and even its most subtle ideas have to be composed from images. We cannot form any theory to explain, say, the workings of nature, without forming in our mind some pattern of movement, some arrangement and rearrangement of the units, which derives from our experience." (Bronowski, 1978 , p 28)

This "scientific/artistic way of knowing" begins with an increased ability to visualize, meanwhile, learning to live with the inherent ambiguity of all visual form. Both artists and scientists are aware that this way of thinking must be solidly grounded in aesthetics. Both groups must develop their ability to process ideas in visual, structural terms in order to think their way into unknown situations. The synchronistic way of knowing concentrates on the visual, imagistic formation of ideas, informed by critical thinking, and leading to a type of purely visual logic. This type of thinking stimulates productive thinking leading to meaningful outcomes that demonstrate the historic interconnection between truth and beauty. There does remain the compelling question: "Will our verbally based, analytical culture ever adequately recognize, develop and utilize the potential of the visual mode of discovery?"

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